Issued May 31, 1912.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE—BULLETIN 107.
HENRY S. GRAVES, Forester.

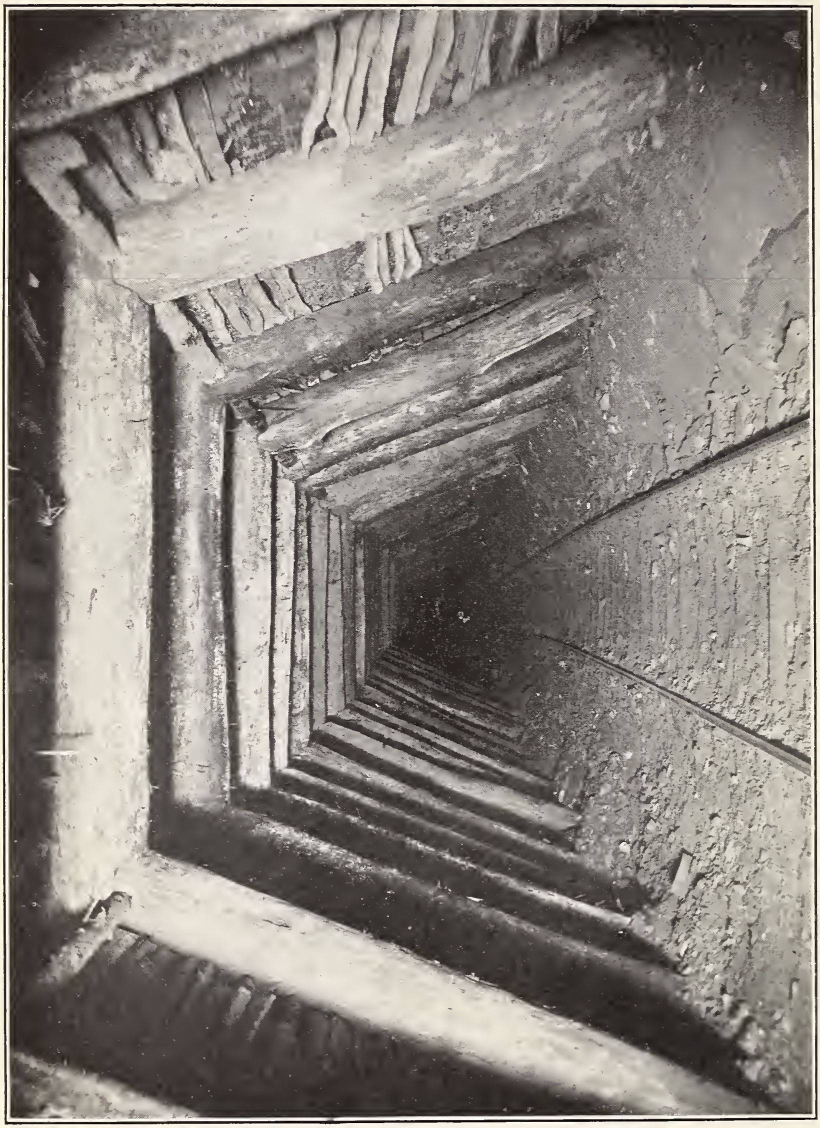
FOREST PRODUCTS LABORATORY SERIES.

THE PRESERVATION OF MINE TIMBERS.

BY

E. W. PETERS,
Engineer in Wood Preservation.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.



GENERAL VIEW OF GANGWAY, PHILADELPHIA & READING COAL & IRON CO.

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
FOREST SERVICE.
Washington, D. C., February 6, 1912.

SIR: I have the honor to transmit herewith a manuscript entitled "The Preservation of Mine Timbers," by E. W. Peters, Engineer in Wood Preservation, and to recommend its publication as Bulletin 107 of the Forest Service.

Respectfully,

HENRY S. GRAVES,
Forester.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE PRESERVATION OF MINE TIMBERS.

OBJECT OF THE STUDY.

In mining operations the cost of timber is a factor of much importance. In 1907, $10,000,000 was spent for round mine props alone,[1] while additional expenditures were necessary for lagging, planking, and other forms of lumber extensively used in mines. The life of mine timbers is in many cases very short, and as the supply of the better grades becomes depleted less durable kinds must be used. This, of course, tends to shorten still further the period of serviceability.

While it is possible that concrete and steel may to some extent take the place of timber in mines, their high cost and the difficulty of installing them will restrict their use to work that is permanent. Moreover, wood, besides being comparatively cheap to handle, possesses so many other desirable qualities that for many purposes a satisfactory substitute is hard to find. Yet the decreasing supply of timber and increasing price make its more efficient utilization imperative.

To secure authentic data on the efficiency of various methods of preserving mine timbers from decay, the Forest Service has carried on a number of investigations in cooperation with various mining companies throughout the United States. These companies are: The Philadelphia & Reading Coal & Iron Co.; the coal mining department of the Delaware, Lackawanna & Western Railroad Co.; the Tennessee Coal, Iron & Railroad Co.; the Bunker Hill & Sullivan Mining & Concentrating Co.; the Hercules Mining Co.; the Homestake Mining Co.; and the Anaconda Copper Mining Co.

These investigations have been conducted along two general lines:

(1) Tests to determine suitable methods of treating timber used in mines.

(2) Tests to determine the durability of treated and untreated timber in actual service.

Some of these tests have already been discussed in Forest Service Circular 111, Prolonging the Life of Mine Timbers, by John M. Nelson, jr. Since its publication, however, additional results of much interest have been secured.

[1] Forest Products of the United States, 1907, Bureau of the Census.

AGENCIES DESTRUCTIVE TO MINE TIMBERS.

Timber used in mines is exposed to destruction from many sources. Wear, breakage, fire, and waste are responsible for much loss. Wooden rollers and drum laggings must be frequently replaced on account of the constant wear by ropes and cables. Unprotected timber used in chutes and mills is also rapidly worn by abrasion, while crossties in main haulage ways are often badly worn by the feet of mules and cut by the rails. Large amounts of timber are broken by "crush" and "squeeze," or by "swelling ground," and much temporary timber is buried beyond recovery in workings which are filled with waste rock or "slush" after the coal or ore has been mined.

Decay and insects, however, cause the greatest damage. If not totally destroyed by one or both of these, the timbers frequently become so weakened that they break under the pressure upon them.

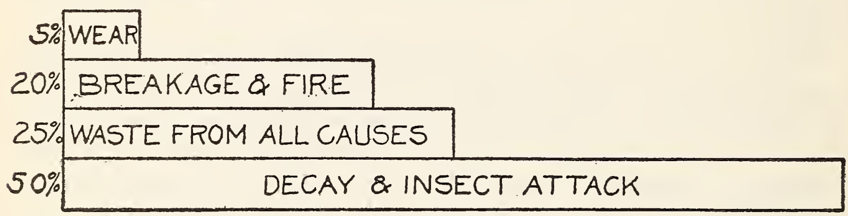

Fig. 1.—The relative importance of agencies destructive to mine timbers under average conditions.

The relative importance of the different destructive agencies varies greatly with conditions within the mines. Figure 1 shows this relative importance as observed in mines of the various cooperating companies.

PRACTICAL METHODS OF INCREASING THE DURABILITY OF TIMBER.

To protect mine timber from destruction by mechanical wear, or by forces of nature beyond human control, is usually impracticable, and preservative treatment of timber exposed to these agencies of destruction, or of that buried in old workings, would be unwarranted. On the other hand, a large amount of timber is destroyed by decay and insects long before it has given its desired service, and if this can be protected at a reasonable cost a considerable saving may be realized.

PEELING.

Peeling timber is a simple and inexpensive method of increasing its durability, and under some conditions is fairly effective. Bark retards the loss of moisture from timber, and unbarked wood therefore offers more favorable conditions for fungus growth than wood from which the bark has been removed. Moreover, the space

between the bark and the wood is an excellent breeding place for many forms of wood-destroying insects. In dry workings the life of timber may be increased from 10 to 15 per cent by peeling, although in wet situations peeling seems to have little effect.

Besides increased durability, there are other advantages to be derived from the use of peeled timber. The bark of unpeeled timber often flakes off soon after placement, causing an accumulation of inflammable rubbish in the workings, which must be removed at some expense. To peel timber in the woods or at the shipping point effects a saving in freight and in cost of handling. With loblolly and shortleaf pine the weight of bark usually amounts to from 8 to 10 per cent of the original green weight.

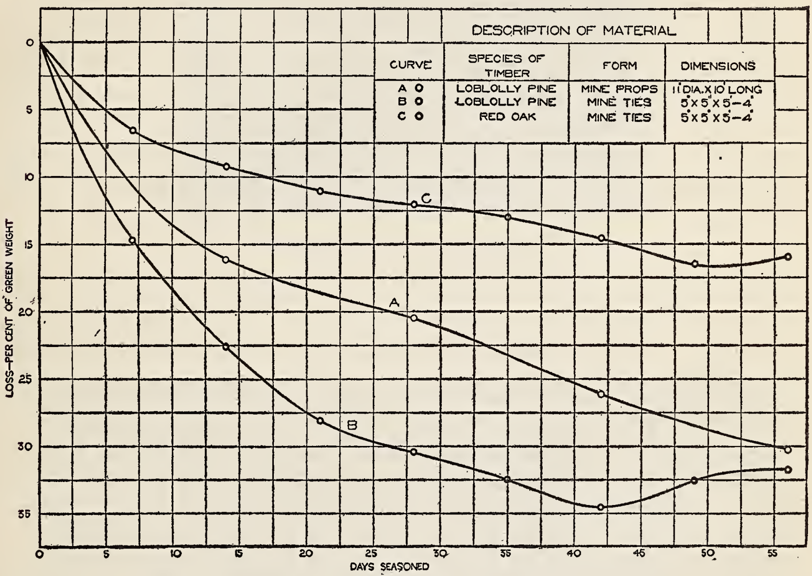

FIG. 2.—Percentage of green weight lost by seasoning mine timbers.

SEASONING.

The durability of timber may in some cases be increased by seasoning. In dry, well-ventilated workings the life of seasoned timber is sometimes 25 per cent greater than that of green timber. In wet locations, however, the effects of seasoning are counteracted by the reabsorption of moisture.

Whenever practicable, timber should be seasoned in the woods or at the shipping point, in order to realize, through loss of weight, a substantial saving in the cost of freight and handling.

Figure 2 shows the rate of seasoning of experimental timbers. Curve *A* shows the percentage of green weight lost in the seasoning of round mine props at Pottsville, Pa. The timbers were first peeled

and then piled on skids. Curves B and C show the rate of seasoning of square-sawed mine ties at Birmingham, Ala. These were placed in open piles immediately after sawing.

The curves indicate that from 15 to 35 per cent of the original green weight was lost in a period of 8 weeks. These tests were carried on during the summer months, and the timbers were piled so as to permit a free circulation of air, conditions favorable to very rapid seasoning.

The diagram indicates that the loss of moisture from loblolly pine is greater than from red oak, and that large timbers season somewhat more slowly than small ones.

To insure thorough seasoning the timbers should be piled with sufficient space between them to permit a free circulation of air throughout the pile. Too rapid seasoning, however, may result in checking, and so weaken the timber. Moreover, if timber is held too long, decay is likely to develop. This is especially true in warm, humid climates, and under such conditions the material should be seasoned as rapidly as possible. Summer-cut timber is also likely to deteriorate while seasoning, and, if possible, cutting should be done at some other time of the year.

PRESERVATIVE TREATMENT.

While, under certain conditions, peeling and seasoning often increase the durability of timber, chemical preservatives give the best results. Before timber is treated with preservatives, however, it should first be peeled, and, as a rule, thoroughly seasoned. All timbers should be cut and framed to their final dimensions and form before treatment, since the sawing and cutting of treated timber frequently exposes untreated surfaces to attack by wood-destroying organisms. A description of the preservatives and of the methods of wood preservation commonly used in this country is given in Forest Service Bulletin 78, Wood Preservation in the United States, by W. F. Sherfesee. A brief description of the several classes of treatments referred to in this bulletin will, however, be given here.

BRUSH TREATMENTS.

A fairly effective and cheap treatment is to paint timber with two or three coats of hot creosote or some similar preservative. It is important that the wood be seasoned before treatment, for otherwise checking may later expose untreated portions of the timber to fungus attack. Care should, moreover, be taken to get the preservative well into all checks, knot holes, and surface inequalities; otherwise decay is likely to develop at these points.

The amount of preservative required for treatments of this character is relatively small, and no special equipment is needed. Brush

FIG. 1.—FUNGOUS GROWTH ON UNTREATED MINE TIMBERS. TIMBER THIRD FROM LEFT WAS TREATED.

FIG. 2.—FUNGOUS GROWTH ON UNTREATED PORTION OF MINE TIMBERS. UPPER PORTION OF TIMBER TREATED, LOWER PORTION UNTREATED.

treatments are therefore advisable when the amount of timber to be treated is too small to warrant the erection of even a small plant, or when it is necessary to restrict the initial cost of treatment to the lowest possible figure. The main disadvantage of brush treatments is that the slight penetration secured is not enough to insure the protection of the interior of the timber for any considerable period. The thin coating of treated wood may be broken or split, or fungus spores may enter through nail holes, checks, or splits, causing decay in the interior of the timber, while the outside appears sound.

OPEN-TANK TREATMENTS.

A more effective method of treatment is the open tank. In this the timber is first immersed in a tank of suitable capacity containing the preservative, and the charge is then heated to a sufficiently high temperature to drive off a portion of the air and moisture contained in the wood. Since excessive heating is likely to result in checks which will weaken the timber, and since large quantities of preservative may be lost by volatilization, the maximum temperature of the hot bath should not, in the case of creosote oils, exceed 220° F. and, if an aqueous salt solution is used, should be kept slightly below the boiling point of the solution.

Following the hot bath the timber is immersed in preservative at a lower temperature, or it may be left in the hot liquid, which is allowed to cool.

The treatment of timber by the open-tank process insures a greater penetration of the wood by the preservative than does the brush method, and for this reason has proved more effective. In general, it is well adapted for the treatment of species which are easily impregnated.

PRESSURE TREATMENTS.

With many species a satisfactory treatment can be secured only by the use of pressure. The essential difference between the open-tank process and the pressure processes is that in the former atmospheric pressure is relied upon to secure the penetration of the wood, while in the latter the preservative is forced into the timber by artificial means. Owing chiefly to the difficulty of impregnating many species of wood by the open-tank process, the pressure treatments are the most widely used.

Pressure processes may be employed for either full cell or empty cell treatment. The object of the former is to leave the treated portion of the wood completely filled with the preservative, while the latter aims to inject the preservative as deep into the timber but leave no free oil in the wood cells. The oldest process of full-

cell pressure treatment with creosote is known as "Bethellizing." A similar treatment with zinc chloride solution is called "Burnettizing."

RESULTS OF EXPERIMENTAL TREATMENTS.

Tables 1 and 2 show the average absorptions and penetrations secured in representative open-tank and pressure treatments of different species of timber. These results indicate that—

(1) Thoroughly seasoned loblolly and Pennsylvania pitch pine round mine timbers may be satisfactorily impregnated by the open-tank process.

(2) Green timber of these species is much more difficult to treat than seasoned timber.

(3) Satisfactory results may be secured in the treatment of seasoned western yellow pine by the open-tank process, the sapwood of this species being impregnated without difficulty.

(4) In general, pressure treatments are more satisfactory than open-tank treatments. By the former the time of treatment is reduced considerably, and the preservative is more generally diffused through the timber.

(5) Heart Douglas fir is impregnated with difficulty.

Table 1.—*Results of representative open-tank creosote treatments of various species.*

Number of treatments averaged.	Description of material.			Record of treatment.				Result of treatment.	
	Species.	Form.	Condition before treatment.	Hot bath.			Cooling bath, duration.	Absorption per cubic foot.	Average penetration.
				Duration.	Maximum temperature.	Average temperature.			
				Hours.	*° F.*	*° F.*	*Hours.*	*Pounds.*	*Inches.*
20	Loblolly pine, largely sapwood.	Round mine props, 10 inches in diameter, 7 to 10 feet long.	Green.....	8–9	226	192	15–16	2.50	¼–½
34	.....do......	.....do........	Partly seasoned, about 2 months.	8–9	231	198	15–16	7.50	¾–1
18	.....do......	.....do........	Well seasoned.	3–4	221	180	5–6	12.20	3–4
20	Pennsylvania pitch pine.	Round mine props, 7 to 10 feet long.	.....do.....	7–8	237	205	15–16	12.20	[1] 2–3
18	Western yellow pine.	Round mine timbers, mine ties.	.....do....	1–2	220	200	½–1	6.90	½–¾

[1] Complete sapwood.

TABLE 2.—*Results of representative creosote pressure treatments of various species.*

Number of treatments averaged.	Description of material.			Description of treatment.	Results of treatment.	
	Species.	Form.	Condition before treatment.		Absorption per cubic foot.	Average penetration.
					Pounds.	*Inches.*
16	Loblolly pine.	Mine ties, 5 by 5 inches by 5 feet 4 inches.	Partly seasoned.	(1) Bath in hot creosote. Average duration of hot bath, 2½ hours; average maximum temperature, 200° to 220° F. (2) Entire charge cooled and pressure applied while cooling. Average duration of cooling bath, 2 to 2½ hours; average pressure, 14 pounds per square inch; average temperature, 190° F.	8.0	1 -2
15	.....do.......	Mine ties, 5 by 5 inches by 5 feet 4 inches.	.....do.......	(1) Bath in hot creosote. Average duration of hot bath, 2¼ hours; average maximum temperature, 200° to 220° F. (2) Cylinder refilled with cool oil and pressure applied. Average duration of cool bath, 1¼ hours; average pressure, 12 pounds per square inch; average temperature, 173° F.	6.2	1 -1½
12	.....do.......	Mine ties, 5 by 5 inches by 5 feet 4 inches.	Well seasoned.	Cylinder filled with creosote and pressure applied. Average duration of pressure, 19 minutes; average pressure, 55 pounds per square inch; average temperature of creosote, 185° F.	8.3	1½-2½
5	Douglas fir..	3-inch planking.	Green.......	(1) Bath in hot creosote. Average duration of hot bath, 4¼ hours; average maximum temperature, 215° F. (2) Entire charge cooled and pressure applied while cooling. Average duration of cooling bath, 2½ hours; average pressure applied, 100 pounds per square inch; average temperature, 198° F.	4.0	¼- ⅜
5	.....do.......	10 by 10 inches and 10 to 14-inch shaft timbers.	.....do.......	(1) Saturate steam bath. Average duration of steam bath, 3 hours; average pressure, 16 to 20 pounds per square inch. (2) Vacuum applied. Average duration of vacuum, 1.9 hours; average vacuum, 16 to 20 inches. (3) Cylinder filled with creosote and pressure applied. Average duration of pressure, 4¾ hours; average pressure, 100 pounds per square inch; average temperature of creosote, 190° to 215° F.	4.0	⅜- ¾

COST OF TREATMENT.

The cost of preservative treatment may be considered under two heads: (1) Cost of treating plants; (2) cost of application and the preservative.

OPEN-TANK PLANTS.

The open tank is the simplest type of apparatus used for the impregnation of timber. The necessary equipment consists mainly of an uncovered tank provided with a device for submerging the timber. The tank may be so arranged that a fire can be built under it, but if a supply of steam is available it should be equipped with coils for heating purposes. If large timbers are to be treated, a derrick or gin pole is necessary for their convenient handling. A plant of this character, with an annual[1] capacity of 100,000 cubic feet, may be erected at a cost of from $1,500 to $2,500. The low cost of an open-tank plant places it well within the reach of most mine operators, and this, perhaps, is its main advantage.

PRESSURE PLANTS.

The cost of pressure plants depends chiefly upon their capacity. Figure 3 shows the general arrangement of a small pressure plant, having a capacity of approximately 1,000 cubic feet per run, or 750,000 cubic feet per year.[2] The total cost of such a plant will amount to from $12,000 to $20,000. The following is a list of the main items of equipment:

One horizontal treating cylinder, 65 feet long, with inside diameter of 6 feet 2 inches, capable of withstanding an internal pressure of 175 pounds per square inch.

Two vertical measuring tanks, each of 15,000 gallons capacity.

One storage tank of 50,000 gallons capacity.

One hoist engine.

One pressure pump, capacity 150 G. P. M. at 175 pounds pressure per square inch.

One air compressor, capacity 460 cubic feet of free air per minute at 20 pounds pressure per square inch.

Sixteen cylinder cars.

One zinc chloride mixing tank of 2,000 gallons capacity.

Special attention should be given to the design and construction of a storage yard of adequate capacity for both treated and untreated material, since handling the timber before and after treatment is an important factor in the cost of operation. It is also important to locate the plant at a convenient point in the mining district, so that treated timber may be readily distributed to points where it is to be used.

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[1] Annual capacity based on two runs per day for 250 days.

[2] Annual capacity based on three runs per day for 250 days.

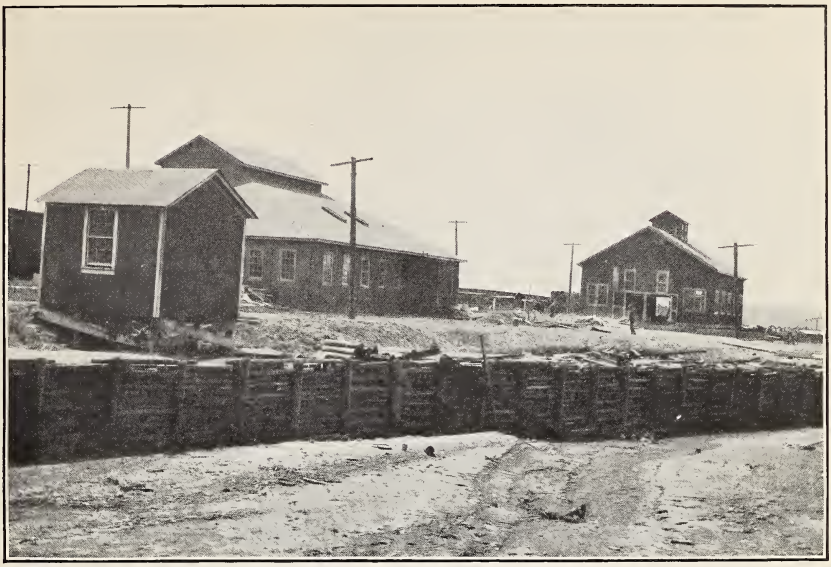


FIG. 1.—WOOD-PRESERVING PLANT AND FRAMING MILL ERECTED BY THE ANACONDA COPPER MINING CO., AT ROCKER, MONT., IN COOPERATION WITH THE FOREST SERVICE.

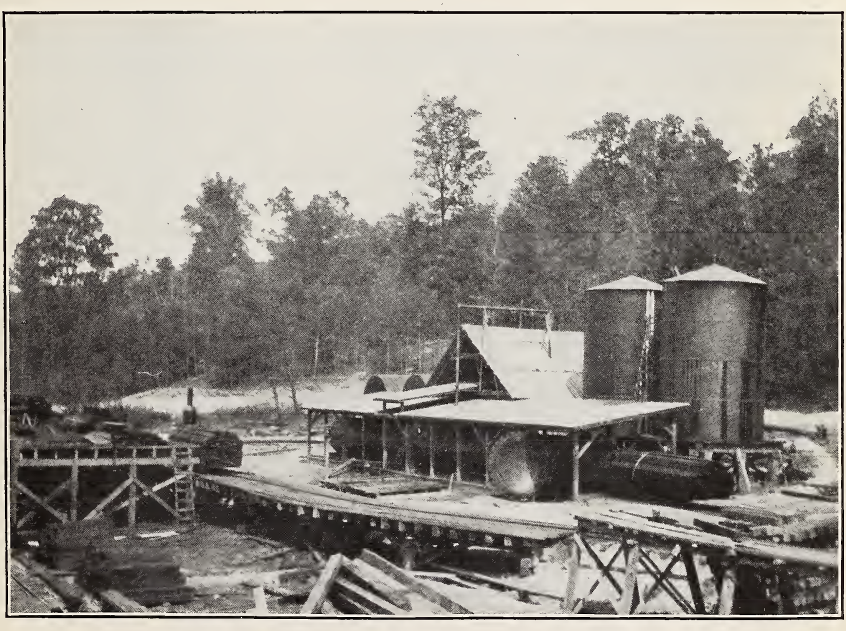


FIG. 2.—WOOD-PRESERVING PLANT ERECTED BY THE TENNESSEE COAL, IRON & RAILROAD CO., AT MCADORY, ALA., IN COOPERATION WITH THE FOREST SERVICE.

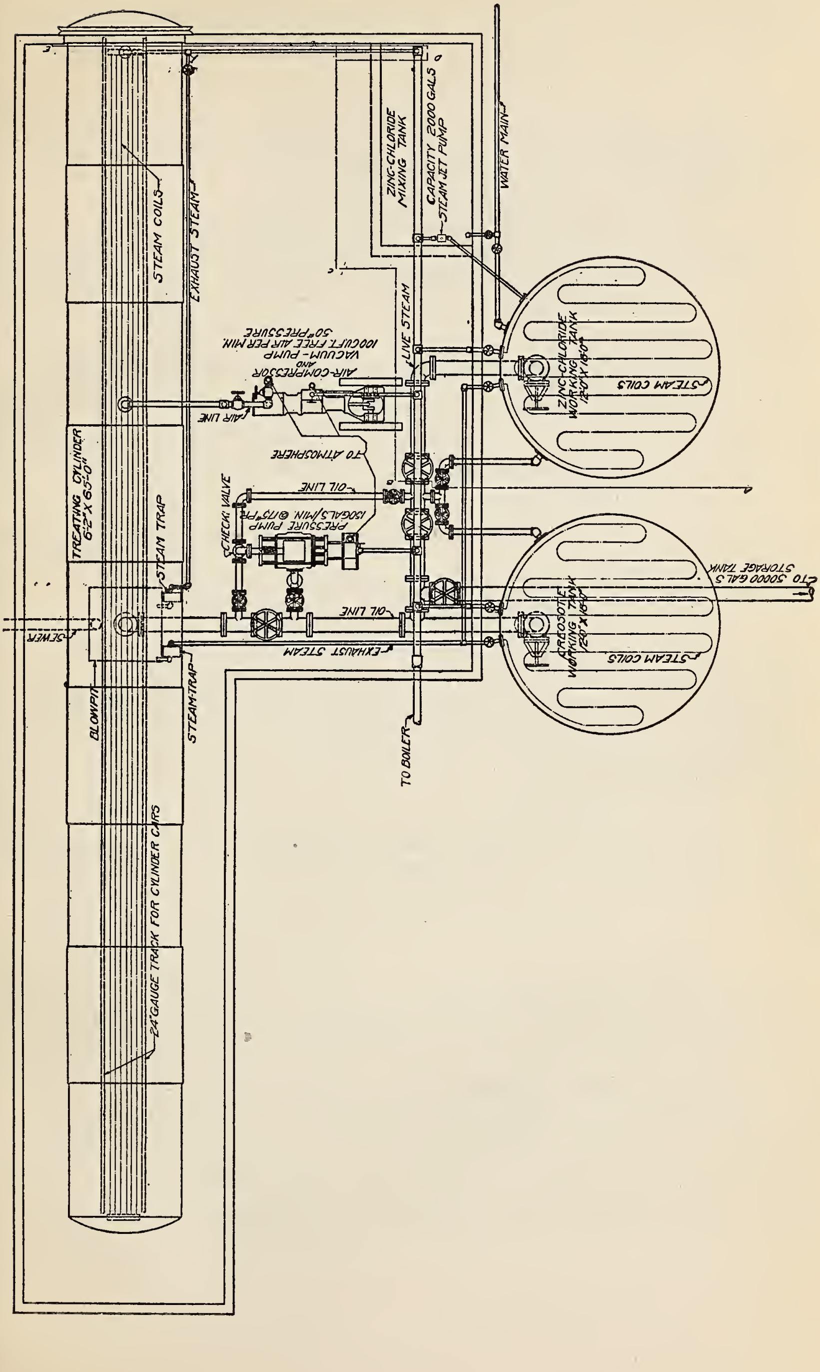


FIG. 3.—General arrangement of small pressure plant for treating timbers.

The pressure plant shown in Plate III, figure 1, was designed by the Forest Service and erected by the Anaconda Copper Mining Co. at Rocker, Mont. Its capacity is about 570 cubic feet of timber per run. The equipment is as follows:

One treating cylinder 43 feet long and 6 feet in diameter, working pressure 100 pounds per square inch.
One receiving tank, 47 feet long and 5 feet in diameter.
Two measuring tanks, 12 feet in diameter and 17 feet high.
One general service pump, 360 G. P. M. at 125 pounds per square inch.
One pressure pump, 60 G. P. M. at 125 pounds per square inch.
One vacuum pump 7 by 10 by 6 inches, and jet condenser.
Eighteen cylinder cars.
One hoist engine.

The total cost of the plant, erected, was approximately $15,000.

Plate III, figure 2, shows a plant designed by the Forest Service for the Tennessee Coal, Iron & Railroad Co., and erected at McAdory, Ala. Its capacity is about 830 cubic feet of timber per run. The main equipment is as follows:

One treating cylinder, 6 feet in diameter and 65 feet long, working pressure 100 pounds per square inch.
Two measuring tanks, 12 feet in diameter and 18 feet high.
Two storage tanks, 11 feet in diameter and 36 feet long.
One settling tank, 16 feet by 6 by 4 feet deep.
One pressure pump, capacity 150 G. P. M. at 100 lbs. per square inch.
One air compressor, capacity 108 cubic feet free air at 50 pounds per square inch.
One air reservoir 3 feet in diameter and 15 feet long.
One surface condenser, 230 square feet of condensing surface.
Twenty cylinder cars.
One derrick and hoist engine.

The total cost of this plant, erected, including the necessary yard construction, amounted to approximately $12,000.

APPLICATION AND PRESERVATIVE.

The unit cost of handling timber at open-tank plants is higher than at pressure plants, usually amounting to from 3 to 4 cents per cubic foot at the former and from 2 to 3 cents per cubic foot at the latter. These figures include interest, depreciation, and operating charges, but not the cost of the preservative, which is by far the most important item. Table 3 shows the approximate costs of the untreated and treated loblolly pine gangway and entry sets used in the Forest Service experiments in the mines of the Philadelphia & Reading Coal & Iron Co.

TABLE 3.—*Cost of untreated and treated loblolly pine gangway and entry sets placed by the Philadelphia & Reading Coal & Iron Co., in cooperation with the Forest Service.*

[One set consists of one 7-foot collar, one 9-foot leg, and one 10-foot leg; average diameter of timbei 13 inches; approximately 26 cubic feet in one set.]

Condition of material before treatment.	Method of treatment.	Preservatives used, sold as—	Unit cost of preservative.	Amount of preservative used per set.	Cost per preservative.	Cost per set of peeling, seasoning, and treating timber.[1]	Total cost of set in workings.
Green unpeeled.	Untreated...	....	....	....	....	....	$8.50
Green peeled....	.....do.......	....	....	....	....	$0.28	8.78
Seasoned peeled	Brush-treated, two coats.	Coal-tar creosote.	8 cents per gallon.[2]	1½ gallons per set, 0.5 pounds per cubic foot.	$0.12	.65	9.27
Do.........	.....do.......	Avenarius carbolineum.	70 cents per gallon.[3]	.....do..........	1.05	.65	10.20
Do.........	Impregnated	Water-gas-tar creosote.	7 cents per gallon.[2]	10 pounds per cubic foot or 30 gallons per set.	2.10	.94	11.54
Do.........	.....do.......	Coal-tar creosote.	8 cents per gallon.[2]	.....do..........	2.40	.94	11.84
Do.........	.....do.......	Zinc chloride..	4 cents per pound dry salt.	½ pound dry salt per cubic foot or 13 pounds per set.	.52	.94	9.96

[1] Cost of treating includes cost of labor, fuel, and interest and depreciation on plant.
[2] Unit cost of creosote based on price of tank car lots of from 8,000 to 10,000 gallons.
[3] Unit cost of carbolineum based on price of barrel lots.

Below is given in detail the cost of untreated and creosoted 16 feet by 8 inches Douglas fir shaft sets placed in the mines of the Anaconda Copper Mining Co. These sets contain 1,127 feet b. m. of Douglas fir squared timbers from the Pacific coast, and 393 feet b. m. of lagging. The average absorption secured in the treatment of these timbers amounted to 4.5 pounds of creosote per cubic foot.

Cost of untreated sets:	
1,127 feet b. m. squared timbers, at $20.50 per M b. m.	$25.36
Framing timbers	13.50
Cost of lagging, at $15 per M b. m.	5.90
Switching and unloading charges	.85
Cost of placing set	18.00
Total cost of untreated set in place	63.61
Cost of treatment:	
Cost of treating, including interest, depreciation, fuel, and labor charges	3.34
Cost of creosote, at 15.6 cents per gallon; absorption 4.5 pounds per cubic foot	8.03
Loading and unloading charges	1.23
Total cost of treatment	12.60
Total cost of treated set in place	76.21

From these examples it is seen that the cost of treating timbers, while a considerable item, does not, when taken in conjunction with the cost of the timber and its preparation and placement, form an unduly high proportion of the whole cost. The actual costs for other mines and other localities will, of course, differ more or less from the figures just given, but they serve to illustrate the relation between the cost of treated and untreated timbers under different conditions.

DURABILITY OF TREATED TIMBERS.

Tests to secure data on the comparative durability of treated and untreated timber, begun by the Forest Service in 1906, in cooperation with the Philadelphia & Reading Coal & Iron Co., and described in this bulletin, have been in progress for a sufficient period to produce results of practical importance. Similar tests are now being carried on in cooperation with other companies, but sufficient time has not elapsed to permit of definite results.

DESCRIPTION OF EXPERIMENTS.

The experimental timbers were standard round "gangway" or "entry" sets, treated and untreated, each set consisting of a 9-foot leg, a 10-foot leg, and a 7-foot cap or collar, the average diameter of the timber being 13 inches. Plate I shows the method of framing the timbers and their extensive use in the mines. The species used were longleaf, loblolly, and shortleaf pine, Pennsylvania pitch pine, and red and black oaks. Table 4 gives the number and condition of the untreated timbers placed.

TABLE 4.—*Untreated experimental timbers placed in the mines of the Philadelphia & Reading Coal & Iron Co.*

Species.	Condition when placed.	Number of pieces.[1]
Loblolly and shortleaf pines	Green, unpeeled	306
Do	Green, peeled	184
Do	Seasoned, peeled	33
Pennsylvania pitch pine	Green, unpeeled	93
Longleaf pine	Green, peeled	48
Red and black oaks	Green, unpeeled	24

[1] Only pieces which are included in the report of the inspections in the Appendix are counted here.

The treated sets included loblolly and shortleaf pine treated by the brush method with creosote and carbolineum, by the open-tank method with various preservatives, and by the pressure method with creosote and zinc chloride. Table 5 gives descriptions of the treated timbers. An analysis of the coal-tar and water-gas-tar creosotes used in the experiments is given in the Appendix.

FIG. 1.—FAILURE FROM CRUSH OF A DECAYED UNTREATED COLLAR AFTER 18 MONTHS' SERVICE, SILVER CREEK COLLIERY, PHILADELPHIA & READING COAL & IRON CO. THE TIMBER TO THE RIGHT, PLACED AT SAME TIME, WAS BURNETTIZED.

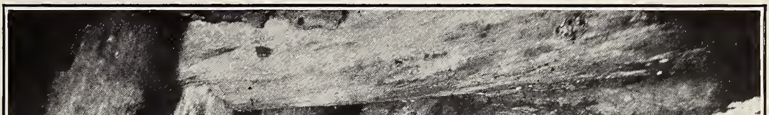


FIG. 2.—FAILURE FROM SQUEEZE OF A DECAYED UNTREATED LOBLOLLY PINE LEG. THE TIMBER DIRECTLY TO THE RIGHT OF THE BROKEN LEG, PLACED AT THE SAME TIME, WAS BETHELLIZED.

TABLE 5.—*Peeled and treated loblolly and shortleaf pine gangway sets placed in the mines of the Philadelphia & Reading Coal & Iron Co.*

Condition before treatment.	Method of treatment.	Preservatives used, sold as—	Amount used.	Number of pieces.
Seasoned...	Brush treated, two coats.	Coal-tar creosote [1]...........	$1\frac{1}{2}$ gallons per set ($\frac{1}{2}$ pound per cubic foot).	24
Do.....	.....do..............	Avenarius carbolineum.....	.....do....................	21
Green......	Open-tank process..	Coal-tar creosote [1]...........	4 to 6 pounds per cubic foot..	138
Do.....	.....do..............	Water-gas-tar creosote.......	.....do....................	147
Do.....	.....do............ .	Zinc chloride [2]..............	$\frac{1}{2}$ pound dry salt per cubic foot.	48
Do.....	.....do..............	Sodium and magnesium chlorides.[3]	1 pound per cubic foot mixture of dry salts.	39
Seasoned...	.....do..............	Coal-tar creosote [1]...........	10 to 12 pounds per cubic foot	135
Do.....	.....do..............	Water-gas tar creosote [1]......	.....do....................	36
Do.....	.....do..............	Zinc chloride [2]..............	$\frac{1}{2}$ pound dry salt per cubic foot.	129
Green......	Bethell process (pressure).	Coal-tar creosote............	10 pounds per cubic foot.....	36
Do.....	Burnett process (pressure).	Zinc chloride [4]..............	0.3 pound dry salt per cubic foot.	87

[1] Analyses of these preservatives are given in the Appendix.
[2] Injected in a 6 per cent aqueous solution.
[3] Injected in a 15 per cent aqueous solution of a mixture consisting of 1 part magnesium chloride to 7 parts of sodium chloride by weight.
[4] Injected in a 2 per cent aqueous solution.

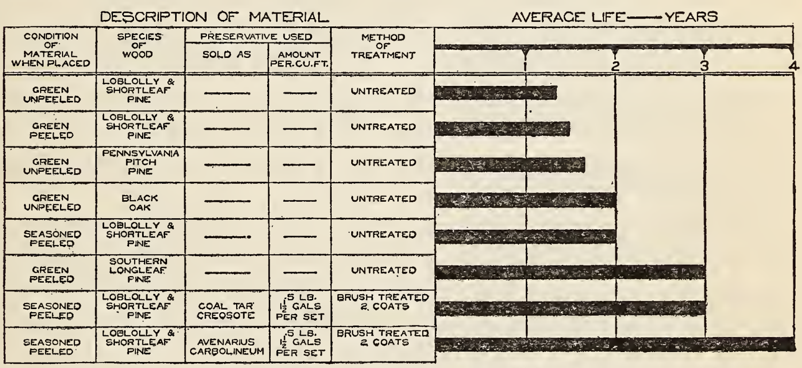


FIG. 4.—Comparative life of untreated and brush treated gangway sets placed in No. 3 plane, Silver Creek colliery of the Philadelphia & Reading Coal & Iron Co., in cooperation with the Forest Service.

LIFE OF TREATED AND UNTREATED TIMBERS.

Most of the timber was placed during 1906, 1907, and 1908; and inspections were made in December, 1907; March, 1909; and July, 1910. The results so far secured are shown graphically in figures 4 and 5. A detailed summary of the inspections is given in Tables 6 and 7.

Owing to the conditions in the various collieries, it was not always possible to make a complete inspection of all of the experimental timbers, nor was it possible in all cases to procure complete data on the cause of failure of individual pieces; but the condition of the timber as found in the various inspections offers sufficiently accurate data to warrant the following conclusions:

(1) All of the untreated material failed within from one to three years, while brush-treated timber remained serviceable for from three to four years.

(2) The life of untreated peeled loblolly and shortleaf pine was from 10 to 15 per cent greater than that of similar unpeeled material.[1]

(3) In dry, well-ventilated workings the average life of untreated seasoned loblolly pine was approximately 25 per cent greater than that of similar green material. In wet locations seasoned timber did not appear to outlast unseasoned material.

(4) Loblolly and shortleaf pine, brush-treated with coal-tar creosote and Avenarius carbolineum, proved to be from 50 to 100 per cent more durable than similar untreated material. Moreover, brush-treated loblolly and shortleaf pine proved more serviceable than untreated longleaf pine, pitch pine, and red and black oak. Brush treatment with Avenarius carbolineum was somewhat more effective than similar treatment with coal-tar creosote.

(5) The condition of timber treated by the open-tank process with sodium and magnesium chloride, although not comparing favorably with that of timber similarly treated with other preservatives, was better than that of the brush-treated timbers.

(6) Open-tank treatments of green timber with zinc chloride proved fairly effective, but the tests indicate that better results will be secured with seasoned material. Figure 5 shows that about 13 per cent of the green timber treated with zinc chloride by the open-tank process showed marked signs of decay after four years, while no decay was found after the same period of service in seasoned material similarly treated.

(7) With the exceptions noted, none of the impregnated timbers showed signs of decay after from three to four years' service, although some of them had failed from crush and squeeze. Plate IV shows to some extent the difference in the condition of treated and untreated material after eighteen months' service.

(8) In some instances impregnated timber, reframed after treatment, showed signs of decay. This was probably due to the cutting away of treated material and the consequent exposure of untreated portions of the timber.

ECONOMY IN THE USE OF TREATED TIMBERS.

SAVING IN MONEY.

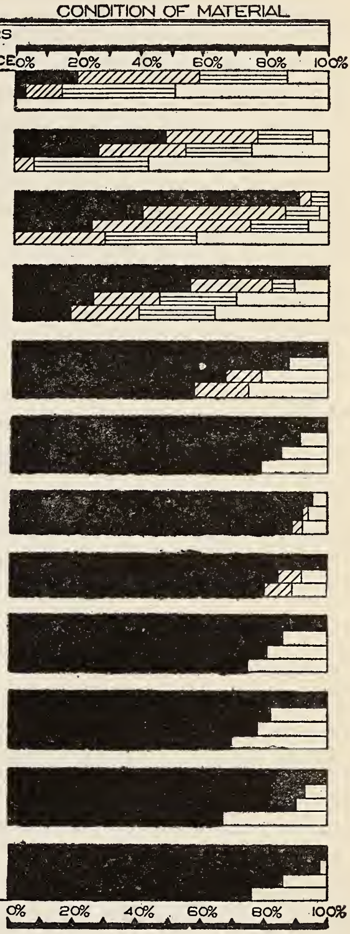
It is not only essential that treated timbers should last longer than untreated ones, but also that this increased life should be sufficient to make their ultimate cost less than for similar untreated material. In other words, an appreciable amount of money must be saved in a reasonable length of time. How much money is actually saved by the use of treated timbers can best be determined by a comparison of the annual charges for the treated and untreated

[1] Most of the timbers were placed in fairly dry situations.

material. By "annual charge" is meant that amount of money which it would be necessary to place aside each year, at compound interest, to amount at the end of the timber's period of service to a sum sufficient to cover the initial cost of the timber in place plus compound interest on the investment.

DESCRIPTION OF MATERIAL

CONDITION OF TIMBER	PERSERVATIVE USED — SOLD AS	PERSERVATIVE USED — AMOUNT PER CU.FT.	METHOD OF APPLICATION	YEARS OF SERVICE
GREEN UNPEELED	——	——	UNTREATED	1 2 3
SEASONED PEELED	COAL TAR CREOSOTE	.5 LB. (1½ GALS. PER SET)	BRUSH TREATMENT 2 COATS	1 2 3
SEASONED PEELED	AVENARIUS CARBOLINEUM	.5 LB. (1½ GALS. PER SET)	BRUSH TREATMENT 2 COATS	1 2 3 4
GREEN PEELED	SODIUM & MAGNESIUM CHLORIDE (5% SOLUTION)	1 LB. DRY SALT	OPEN TANK PROCESS	1 2 3 4
GREEN PEELED	ZINC CHLORIDE (6% SOLUTION)	½ LB. DRY SALT	OPEN TANK PROCESS	1 2 3 4
SEASONED PEELED	ZINC CHLORIDE (6% SOLUTION)	½ LB. DRY SALT	OPEN TANK PROCESS	1 2 3 4
GREEN PEELED	WATER GAS TAR CREOSOTE	4-6 LBS.	OPEN TANK PROCESS	1 2 3
SEASONED PEELED	WATER GAS TAR CREOSOTE	10-12 LBS.	OPEN TANK PROCESS	1 2 3
GREEN PEELED	COAL TAR CREOSOTE	4-6 LBS.	OPEN TANK PROCESS	1 2 3 4
SEASONED PEELED	COAL TAR CREOSOTE	10-12 LBS.	OPEN TANK PROCESS	1 2 3 4
GREEN PEELED	COAL TAR CREOSOTE	10 LBS.	BETHEL PROCESS	1 2 3 4
GREEN PEELED	ZINC CHLORIDE (2% SOLUTION)	.3 LB. DRY SALT	BURNETT PROCESS	1 2 3 4



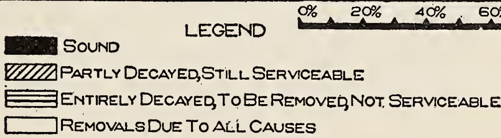


FIG. 5.—Comparative condition of treated and untreated loblolly pine gangway sets placed in the mines of the Philadelphia & Reading Coal & Iron Company.

Figure 6 shows graphically the actual length of service secured from both the treated and untreated timbers set in the mines of the Philadelphia & Reading Coal & Iron Co. as observed at the time of the last inspection. It also shows the length of life necessary for treated timbers to make the annual charges equal to those for similar

untreated material.[1] For example, if the annual charge on peeled timber is to equal that on unpeeled timber the life of the former must be about one year and six months. The average life of peeled timber was found to be slightly higher than this. Timbers impregnated with zinc chloride should have a life of one year and eight months to make the treatment economical. At the date of the last inspection these timbers had already been in service for a period of three years and seven months, and 78 per cent of them were still sound. Figure 7 shows in fact that the increased service obtained by the use of a preservative treatment was in all cases sufficient to bring about a saving in money. It indicates further that in these experiments impregnated timbers have proved more economical than brush-treated ones. Moreover, for the period since placement, the zinc chloride treatments show the greatest efficiency. Enough time has

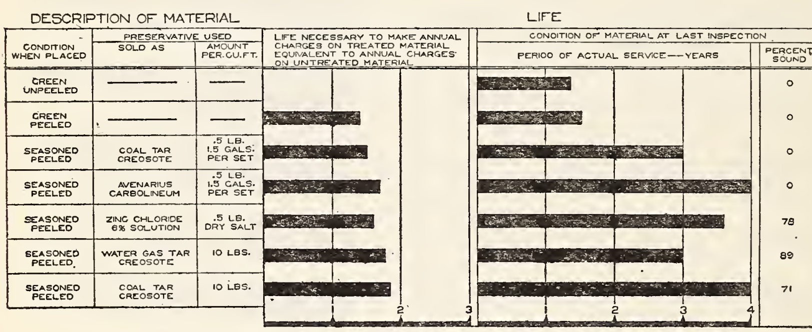


FIG. 6.—Comparative life of treated and untreated loblolly pine gangway sets.

not elapsed, however, to warrant a definite statement concerning the comparative efficiency of timbers impregnated with zinc chloride, with coal-tar creosote, and with water-gas-tar creosote.

Figure 6 shows graphically the comparative cost of untreated and of brush-treated loblolly pine gangway sets after various periods of service. The charge includes the cost of installation and maintenance, plus simple interest at 5 per cent on the investment, and was derived from the cost data given in Table 3 and the figures for average life secured from the experimental sets placed in the mines of the Philadelphia & Reading Coal & Iron Co., as shown in figure 4. The broken lines show the actual expenditures for a gangway set of average life.

Thus the original cost of a green unpeeled and untreated loblolly pine gangway set, including removal of old timber and placement of

[1] Annual charges computed from the following formula:

$$A = P\frac{(1+r)^{n}\,r}{(1+r)^{n}-1}$$

in which A = annual charge;
P = amount of initial investment;
n = number of years in recurring period;
r = rate of interest expressed decimally (in this case taken as 5 per cent).

new ones, amounts to about \$8.50. The average life of such a set is about one year and four months. At the end of this period the simple interest charges on the expenditure amount to \$0.57, making the total cost up to that time \$9.07, as indicated on line *A*. To this must be added a replacement charge of \$8.50, which is represented by the vertical rise in this line; the total charges for the two installations and the maintenance and simple interest on the first installation up to this time amounting to \$17.57. After a period of two years and eight months the interest charges on the cost of the first

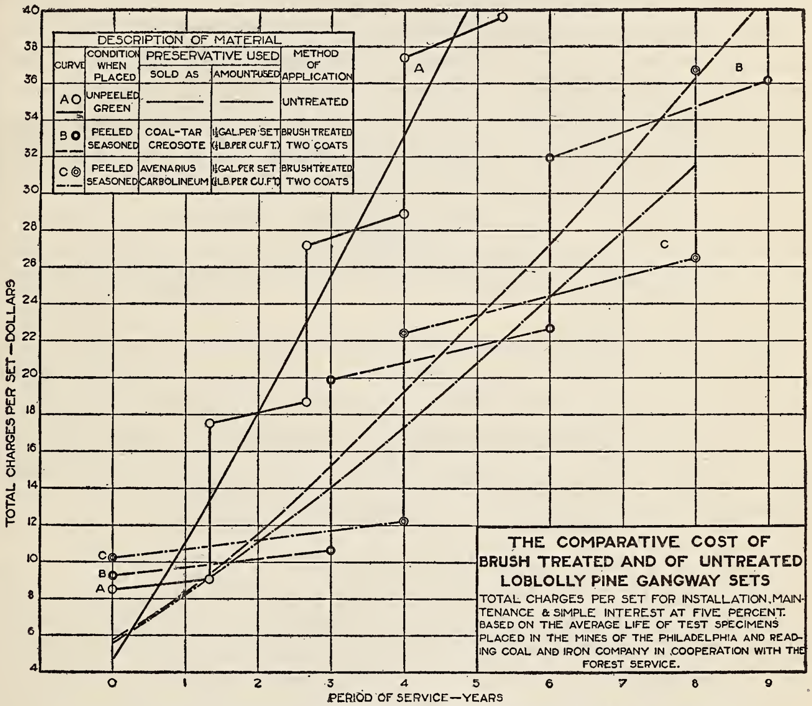


FIG. 7.—Comparative cost of brush treated and of untreated loblolly pine gangway sets.

installation amount to \$1.14, and on the first replacement to \$0.57, making the total cost up to this time \$18.71. A second replacement is then necessary, the cost of which is again shown by the second vertical rise in the line. Thus the increased interest charges are represented by the increase in the slope of the lines connecting the vertical rises in the broken line, while the vertical rises represent the successive replacement charges. Lines *B* and *C*, showing the cost of brush-treated sets, are derived in a similar manner.

If a number of sets are considered it is unlikely that all of them will fail at the same time, and for this reason the average expenditures are better represented by the smooth curves shown in the diagram.

These also show better the saving which may be realized by the use of brush-treated timber. Thus in two years the average total charges against the untreated set, as read from the curve, amount to about $18.10. With a set brush-treated with creosote, on the other hand, the charges amount to $11.60, a saving of $6.50 due to the treatment. In four years this saving amounts to $13.80, which represents the difference between $33, the total cost of the untreated sets, and $19.20, the total cost of the brush-treated sets for that period. The curves further indicate that brush treatment with carbolineum proved more economical than brush treatment with creosote. The fact that the initial cost of the timber at different periods is considered to be the same makes the curves very conservative, since the price of mine timbers will unquestionably continue to rise. On the other hand, a certain salvage might have been allowed for removed props, which may be utilized for fuel or sawed into lagging. Since, under the conditions of the experiment, failure from mechanical causes, such as crush and squeeze, was more common in treated than untreated props, the former would have a greater salvage value, and the relative saving resulting from their use would be greater than that shown in the diagram.

Since the impregnated timbers have not been in service long enough to enable their average life to be determined, most of them being still sound when last inspected, it is impossible to show the ultimate saving in money resulting from their use. Even for the period since their installation, however, they have proved more economical than untreated or brush-treated material.

SAVING IN TIMBER.

Not only will proper preservative treatment result in a direct saving in money, but it will make less timber necessary for any given working. Furthermore, the use of treated timber makes it possible to utilize many of the inferior and more rapid growing species, which, though possessing most of the requirements of high-grade structural timber, lack durability. Treated timber of these species has in many cases proved more serviceable than high-grade untreated material. Thus, in the eastern and southern States, treated loblolly and shortleaf pines may take the place of untreated longleaf pine, while treated red and black oaks may be substituted for untreated white oak. Douglas fir, which is now extensively used in the West, may in turn be replaced by treated hemlock, larch, or western yellow pine. Inferior grades of timber can usually be bought for less than higher grades, and an additional saving thus realized.

AVOIDANCE OF WASTE.

Timber which is to be treated should, whenever possible, be round instead of square, since the sapwood of most species is more easily impregnated than the heartwood. Moreover, the use of round timbers will do away with the cost of sawing and the consequent waste.

A further economy of waste may be effected by careful inspection, and a rigid condemnation of all unsound material. This is especially important where the timber is to be treated, for it is poor economy to apply an expensive preservative treatment to defective material.

The utilization of waste mine timbers has sometimes proved profitable. Sound sections of broken or partly decayed props have been sawed or split into laggings, planking, etc., and in some cases it has been found profitable to use this material for fuel or to sell it for pulp wood. In many cases such methods afford a considerable saving and also provide a means of disposal for waste.

SUMMARY.

The results of the investigations discussed in this bulletin may be summarized as follows:

(1) Decay is, in general, the agency most destructive to timber used in mines.

(2) Although decay may often be retarded by peeling and seasoning, treatment with a suitable preservative is more effective.

(3) The average life of green, unpeeled, and untreated loblolly-pine gangway sets, under the conditions of the experiments discussed, was less than one and one-half years. Brush treatments with creosote and carbolineum increased this to three and four years, while impregnation treatments with zinc chloride and creosote left from 70 to 90 per cent of the timbers sound at the end of four years.

(4) The use of treated timber results in a saving in the cost of maintenance of workings and a reduction in the amount of timber required and makes possible the utilization of inferior species of wood.

(5) Brush treatments are economical when the amount of timber to be treated will not warrant the erection of a small open-tank or pressure plant, or when only a short increase in service is required.

(6) The open-tank process is adapted to the treatment of small quantities of easily impregnated timber. When a large amount of material is to be treated, a pressure process should be used.

(7) Mine timbers impregnated with zinc chloride and creosote oils have shown the best results. Up to the present, no difference in their durability has been noted.

(8) An efficient system of inspection and careful supervision in the use of timber will reduce waste and result in considerable economy. Necessary waste can in many cases be utilized.

APPENDIX.

ANALYSIS OF PRESERVATIVES.

Samples of the preservatives sold as coal-tar creosote and water-gas-tar creosote, and used in the experiments described in this bulletin, were analyzed in accordance with the method described in Forest Service Circular 112, "The Analysis and Grading of Creosote," by Arthur L. Dean and Ernest Bateman.

Analysis of Coal-Tar Creosote.

Original oil.—Green color, almost solid at ordinary temperature, specific gravity at 50° C.=1.0330. Fractional distillation.

Fraction.	Temperature.	Distillate.	Index of refraction.	Character of fraction.
	° *C.*	*Per cent.*		
No. 1	170	16.60	....	Milky liquid, floating solid, 12.9 per cent water.
No. 2	205	1.57	....	White, crystalline, solid.
No. 3	215	6.68	1.5757	Nearly white, crystalline, solid.
No. 4	225	43.92	....	Pale yellow, crystalline, solid.
No. 5	235	4.35	1.5903	Do.
No. 6	245	1.41	1.5965	Yellow, clear, liquid.
No. 7	255	.70	1.5980	Brownish, yellow, clear, liquid.
No. 8	265	1.07	1.6003	Yellow, clear, liquid.
No. 9	275	1.32	1.6052	Do.
No. 10	285	1.76	1.6111	Do.
No. 11	295	1.93	1.6191	Bright yellow, solid.
No. 12	305	1.89	....	Do.
No. 13	320	2.70	....	Do.
No. 14	330	3.34	....	Dark yellow, solid.
Residue	....	9.78	....	Red-brown paste, soft at 60° C.

The sulphonation test was applied to the fractions distilling between 285° C. and 295° C. A residue of 2.9 per cent was obtained from the former, and of 2.5 per cent from the latter.

Analysis of Water-Gas Tar Creosote.

Original oil.—Reddish brown, no crystalline solids, green fluorescence, specific gravity at 50° C.=1.0641. Fractional distillation.

Fraction.	Temperature.	Distillate.	Index of refraction.	Character of fraction.
	° *C.*	*Per cent.*		
No. 1	170	0.83	1.4819	Faint pink, clear oil.
No. 2	205	1.50	1.4951	Scarlet, clear oil.
No. 3	215	.38	1.5153	Claret, clear oil.
No. 4	225	.47	1.5277	Deep brownish-red, clear oil.
No. 5	235	.44	1.5385	Very deep red oil.
No. 6	245	.56	1.5511	Do.
No. 7	255	.81	1.5629	Gray black, not clear oil.
No. 8	265	1.00	1.5753	Do.
No. 9	275	1.55	....	Brown black, not clear, water.
No. 10	285	3.07	1.5885	Brown red, clear oil.
No. 11	295	2.26	1.5951	Deep brown red, clear oil.
No. 12	305	2.80	1.6041	Deep claret, clear oil.
No. 13	320	6.59	1.6126	Do.
No. 14	330	5.98	1.6232	Yellow brown, clear oil.
No. 15	340	6.43	1.6349	Golden, clear oil.
No. 16	350	13.19	1.6477	Do.
No. 17	360	9.35	1.6559	Orange red, clear liquid.
No. 18	370	10.27	1.6634	Do.
No. 19	380	6.92	....	Do.
No. 20	400	9.97	....	Yellow crystalline, solid.
Residue	....	15.26	....	Red-brown pitch, burnt odor.

The sulphonation test was not applied.

TABLE 6.—*Summary report of first, second, and third inspection of experimental timbers placed in No. 3 Plane, Silver Creek Colliery, of the Philadelphia & Reading Coal & Iron Co.*

Description of material.	Results of first inspection.							Results of second inspection.							Results of third inspection.						
	Average period of service.		Number of pieces inspected.	Number sound.	Number partly decayed.	Number entirely decayed.	Removals from all causes.	Average period of service.		Number of pieces inspected.	Number sound.	Number partly decayed.	Number entirely decayed.	Removals from all causes.	Average period of service.		Number of pieces inspected.	Number sound.	Number partly decayed.	Number entirely decayed.	Removals from all causes.
	Yr.	*Mo.*						*Yr.*	*Mo.*						*Yr.*	*Mo.*					
Loblolly and shortleaf pine, green, unpeeled, and untreated	1	5	162	9	66	53	34	2	8	174	0	7	50	117	4	0	90	0	0	0	90
	1	2	72	14	33	18	7	2	5	187	2	14	23	48	3	9	36	0	0	0	36
	0	10	36	18	15	3	0	2	1	33	3	6	0	24	3	5	15	0	0	0	15
	0	5	12	3	0	3	6	1	8	8	0	0	3	5	3	0	12	0	0	0	12
								1	2	42	0	3	15	24	2	6	51	0	3	24	24
Loblolly and shortleaf pine, green, peeled, and untreated	1	5	36	3	18	6	9	2	8	36	3	0	26	7	4	0	9	0	0	0	9
	1	1	12	3	3	0	6	2	4	21	0	3	3	15	3	8	21	0	0	0	21
	0	10	30	16	14	0	0	2	1	37	4	13	8	12	3	5	9	0	3	0	6
	0	6	51	39	6	0	6	1	9	87	7	25	17	38	3	2	63	0	0	0	63
								1	2	15	0	2	4	9							
Loblolly and shortleaf pine, green, peeled, brush treated with creosote	1	5	48	32	10	0	6	2	8	51	7	24	7	13	4	0	18				18
								1	11	6	3	3	0	0	3	4	6	3	0	0	3
Loblolly and shortleaf pine, seasoned, peeled, brush treated with creosote	1	5	15	6	3	3	3	2	8	21	3	8	7	3	4	0	21			6	15
								2	4	3	3	0	0	0	3	4	3				3
Loblolly and shortleaf pine, green, peeled, brush treated with carbolineum	1	5	39	18	18	3	0	2	8	42	9	25	2	6	4	0	9			3	6
Loblolly and shortleaf pine, seasoned, peeled, brush treated with carbolineum	1	5	12	9	0	3	0	2	8	18	3	11	3	1	4	0	18	0	6	6	6
								2	4	3	3				3	8	3				3
Loblolly and shortleaf pine, green, peeled, treated with sodium and magnesium chloride by the open-tank process	0	6	21	21	0	0	0	1	8	39	25	8	2	4	3	2	24	6	5	6	7
								1	1	12	3			9	2	5	3	3	0	0	0
Loblolly and shortleaf pine, green, peeled, treated with coal-tar creosote by the open-tank process	1	5	42	42				2	8	69	62	0	0	7	4	0	12	6	0	0	6
	1	2	45	45				2	5	78	69	0	0	9	3	9	45	45			
	0	10	39	39				2	1	108	98	1	0	9	3	5	66	48			18
	0	5	15	15				1	8	33	27	0	0	6	3	0	12				12
															2	6	18	18			
Loblolly and shortleaf pine, seasoned, peeled, treated with coal-tar creosote by the open-tank process	1	5	15	15				2	8	48	39	0	0	9	4	0	42	30			12
								2	4	18	15	0	0	3							
	0	9	21	21				2	0	69	54	0	0	15	3	4	27	21			6
															2	6	27	27			
Loblolly and shortleaf pine, green, peeled, treated with oil-tar creosote by the open-tank process	0	5	6	6				1	8	9	9				3	0	3				3
								1	1	42	36			6	2	5	72	69			3
								0	9	66				66	2	1	69	63	3	0	3

Loblolly and shortleaf pine, seasoned, peeled, treated with oil-tar creosote by the open-tank process	.....	.....	.....	.....	.....	.....	1 1	36	36	.....	.....	.....	2 5	33	27	3	0	3
Loblolly pine, burnettized	1 3	54	53	.....	.....	1	2 6	87	78	.....	.....	9	3 10	51	39	.....	.....	12
Loblolly pine, bethellized	1 4	21	21	.....	.....	.....	2 5	36	33	.....	.....	3	3 9	24	18	.....	.....	6
Loblolly and shortleaf pine, green, treated with zinc chloride by the open-tank process	0 8	15	15	.....	.....	.....	1 11	18	15	.....	.....	3	3 4	6	3	3	.....	.....
	.....	.....	.....	.....	.....	.....	1 0	30	30	.....	.....	.....	2 5	18	12	.....	.....	6
Loblolly and shortleaf pine, seasoned, treated with zinc chloride by the open-tank process	0 9	24	24	0	0	0	2 0	39	39	.....	.....	.....	3 4	9	3	.....	.....	6
	0 7	21	21	0	0	0	1 10	45	42	.....	.....	3	3 2	21	12	.....	.....	9
	.....	.....	.....	.....	.....	.....	1 1	45	39	.....	.....	6	2 5	72	66	.....	.....	6
Longleaf pine, green, peeled, untreated	0 10	21	9	9	.....	3	2 1	21	4	8	6	3	3 6	6	.....	.....	.....	6
Pitch pine, green, unpeeled, untreated	1 3	15	2	.....	6	7	2 6	27	.....	3	14	10	3 11	27	.....	.....	.....	27
Black oak, green, unpeeled, untreated	1 2	9	6	3	.....	.....	2 5	18	.....	12	.....	6	3 10	15	.....	.....	.....	15

TABLE 7.—*Summary inspection of experimental timbers placed in West Skidmore, lower level, Eagle Hill Colliery of the Philadelphia & Reading Coal & Iron Co.*

Description of material.	Results of first inspection.					
	Average period of service.	Pieces inspected.	Sound.	Partly decayed.	Entirely decayed.	Removals from all causes.
	Yrs. mos.	*No.*	*No.*	*No.*	*No.*	*No.*
Loblolly pine, green, unpeeled, untreated	2 5	69	3	19	14	33
Loblolly pine, peeled, untreated	2 7	78	21	15	6	36
Loblolly pine, seasoned, peeled, brush treated with coal-tar creosote	2 7	57	30	9	3	15
Loblolly pine, green, peeled, treated with coal-tar creosote by the open-tank process	2 3	21	21	.....	.....	.....